Mineral Resources: Geology, Exploration, Economics and Environment

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Lecture - 45
Mineral Inventory Estimation

Welcome to Today's lecture, we have been discussing about the mineral inventory estimation and we were just got into the discussion about the about the parameter which is call the cut off grade and this cut off grade is can be calculated in a very simplistic idea can be made through this expression.

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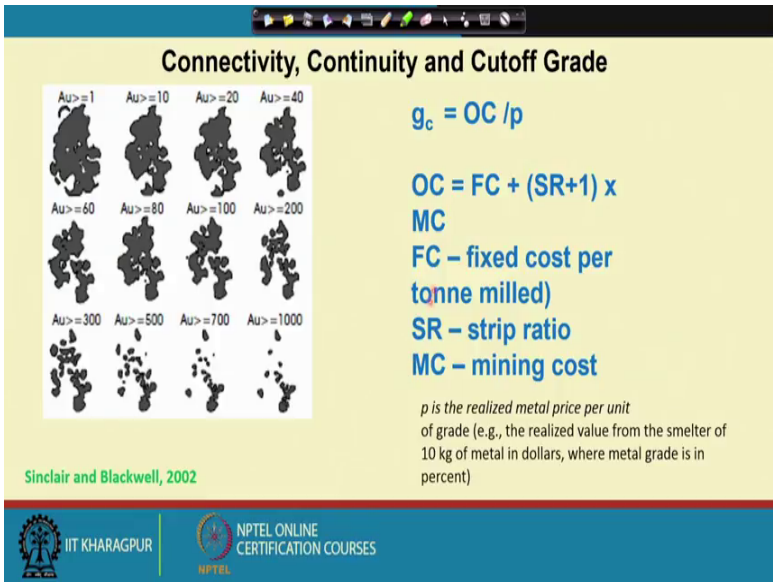

That a cut off grade is essentially is a parameter which is estimated depending on the prevailing cost of that particular metal of interest which is being which will be marketed and will give the revenue to the mineral, to the mining body which is doing the mining the mining agency and this parameter will be used for classification into ore and waste and its worth remembering that this cut off grade is also not a very sacrosanct very fixed parameter which is also likely to change with the with the change or the development in many techno economics parameters. So, without getting much into it we will just have a quick look on some of the other aspects.

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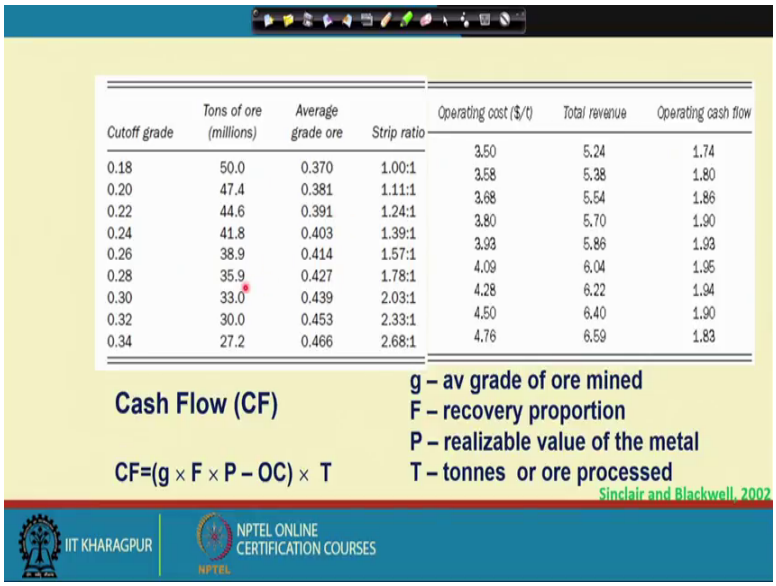

So, from this table here we can make an make an idea of what exactly goes on, this a cash flow is a is an economic parameter which is one of the major. It is a very key parameter for the for assessing the economic aspect of any mine mining industry any mining any operating mine or mine company which is responsible in doing the mining activity.

So, this cash flow is a, is a thing which is depending on the average grade of the ore mined the recovery proportion the realisable value and the operating cost into the tonnes of the metal that is proposed and here we could get some idea about what happens. Suppose, we fix a cut off grade and let us see what happens if the cut off grade is increased.

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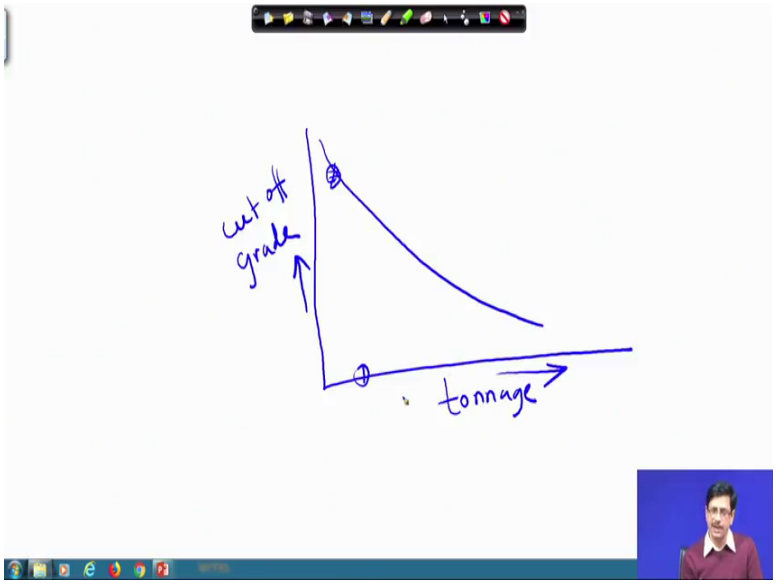

If the cut here is a hypothetical example of the cut off grade being increased from 0.8, 0.18 to 0.34 and it always happens that a that the grade and tonnage will always they follow a an inverse kind of relationship.

So, it will always be something like this, say tonnage is increasing in this direction and grade is increasing in this direction. So, if we increase the, if we think of higher and higher grade or higher and higher cut off grade. So, let us say it is a cut off grade. So, means if the cut off grade is high then the total amount that is available to us from the ore body in terms of the tonnage of the ore will be less, if we make a relaxation and go on decreasing the cut off grade then we have more and more among the more and more quantity of the ore that could be classified or more in quantity from the ore body which can be classified as ore can be mine.

So, we see here the same thing that if we increase the cut off grade, the total tonnes of mine is basically decreasing from 50 to 27.2 million tonnes and the average grade ore is also increasing from 0.37 to 466 because the cut off grade is the lowest value whereas, the grade acceptable grade can always vary in we have been in wide ranges and we can think of what is the average grade that we are mining. And that also will increase with the increasing of the cut off grade and also we see that the strip ratio in case when the cut off grade was one it from with the cut off grade went up from 0.18 to 0.34 the strip ratio went on increasing from 1 is to 1 to 2.68 is to 1 means, 2.68 times the amount of material

could be discarded as waste if the cut off grade is increase which is very well understandable.

And we also see that if the cut off grade goes on increasing the operating cost also goes on increasing in terms of whichever currency think of as a dollar per tonne or it is rupee per tonne, lakhs of rupees per tonne whatever. So, here its going from its also increasing and the total revenue on is also increasing because we are mining higher and higher grade of material and the operating cash flow is also increasing from 1.74 to 1.83.

So, this table and the values that are tabulated here gives us some idea about what exactly the economic parameters and which help in the feasibility analysis and the economic analysis of the ore deposit in deciding whether the ore body will be worth mining or not.

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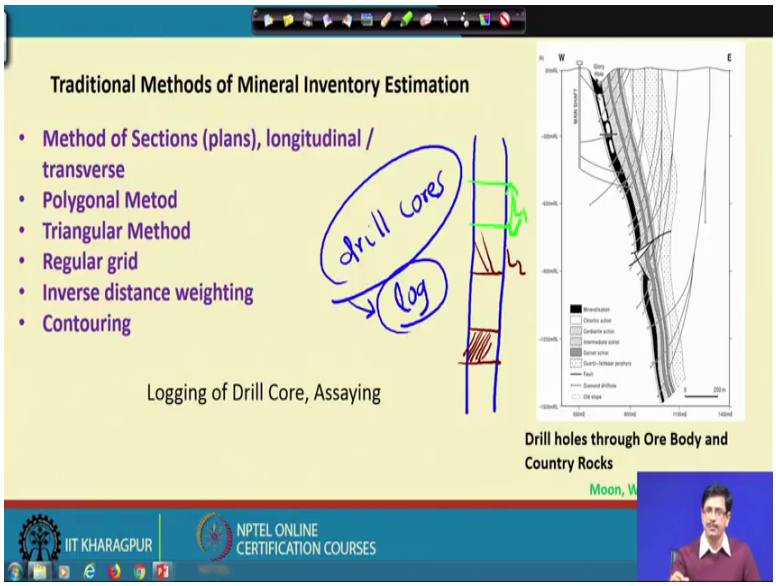

So, they from here, we can just have a quick look on the traditional methods of the mineral inventory estimation this diagram is just for a general look or just to have an have a feel of what exactly is. So, this is this shows a drill did series of drill holes, which are cut or which are made through the ore body and the country rock and if suppose this could have been the part which is on the surface and we just get some idea about the nature of the ore body, but until and unless these series of drill holes away in space from the part which were the ore body is suspected to be present and the ore drill holes are sunken difference special distance away. If that the this happens this is a as thinking that

this north, south striking ore body and this is an east, west section and then it is usually once the ore bodies dip is somehow determined or is or is speculated then the drill holes have to be made from the opposite side from the from the direction from the. So, that the drill holes actually intersects the ore body because from this side the drill holes will always go parallel or will not be its always more convenient to put the drill holes exactly in the opposite direction which the ore body is dipping.

So, this traditional methods are essentially methods we can think of methods of sections plants or longitudinal or transverse sections, polygonal methods, triangular methods, regular grids, inverse distance weighting, contouring which will be seeing here, but before that it is the its beyond the scope of this discussion to go into details of the drilling. But, the exercise involves essentially the kind of drilling that is done in this situations is to recover the drill cores in any drilling practice the method of drilling which is employed is essentially the drill cores, drill cores are recover in terms of in in length and cylindrical masses which exactly mimics the drill pipe which goes deeper and recovers the core the material from below.

So, the drill core in several 100s of metres of length sometimes from several 100s of meters of drill cores are recovered in this kind of drilling process and for generally the job of a geologist is to log the drill cores in terms of what exactly the lithology the type of rocks that encountered different depths and to make a proper documentation of what exactly are present a different depths and that is essentially the process of the logging of the drill cores. So, that from which it could be nicely documented.

For example if there is a drill if there is a drill core which is recovered like this and in this particular drill core it might be that for a particular depth there could be some lithology say for example, say lithology 1 and maybe for another depth there could be lithology 2 and for a depth up to this say for example, this is the ore and similarly it may be that there could be just as particular depth span it which the drill core as into drill has intersected an ore body.

Now, what? So, what has to be done is the is that through series of such drill holes which are made distances away from the, from a centre point with an intention to intersect the ore body at greater and greater depths and then to reconstruct the 3 dimensional geometric by stacking by using all this drill core sections and the correlate them to

understand the geometry of the ore body, a small example which is shown here. Means this particular ore body geometry has been reconstructed here by the drills with the drill cores where recovered and we are logged in terms of what exactly lithologys were encountered at what depth and even though sometimes it is not that very straight forward there could be many situations whether could be drill loss of the materials during the drilling, there could be subsurface structures some brittle zone or some zone and which the cores cannot be recovered this thing are well worked out or well understood and the plugging methods and the reconstruction of the 3 dimensional geometry is somehow is done through the process.

So, this process essentially by that the subsurface and then the whatever cores are recovered from their present when it intersect the ore body, if it happens to be discrete ore body or it may be a situation where the ore body could only be define by virtue of a higher concentration of a particular metal. In either of the cases the mineralised zones thick in terms of thickness depth of extension and the along strike extensions all could be worked out and reconstructed and reconstructed in terms of 3 dimensional diagrams, from which it will be easy to understand how to work out the quantity and quality parameters.

Because in every drill hole wherever the ore body is encountered the assaying is done in terms of a measurement of the concentration of the metals.

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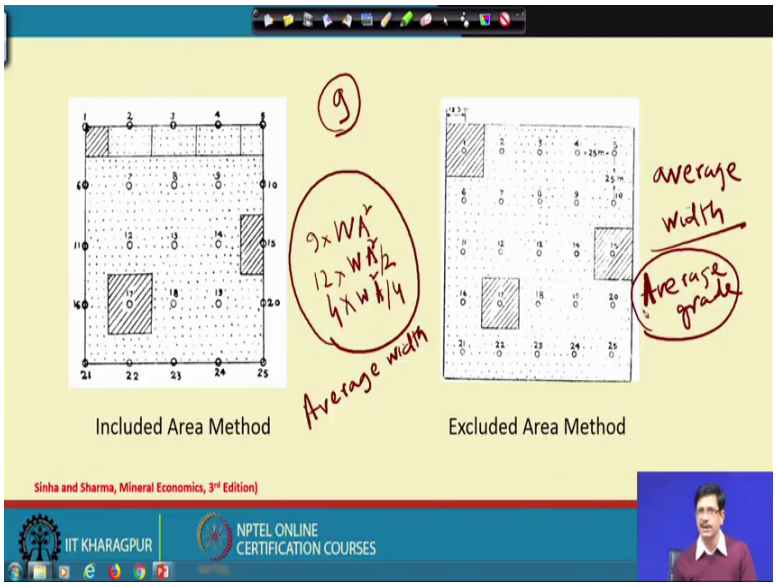

Suppose take a very simple example that the ore body is essentially is a horizontal, if talker it is occurs at a great depth, but the body can be first presume let us presume that the ore body is perfectly horizontal ore body and the points over here is that only 5 points here 1, 2, 5 and there are 5 such profiles and the drill drilling has been done and each drill has been logged and at what depth the ore body has been encountered and with what width the ore body is encountered is documented.

Now, if you want to. So, the exercise could be how to find out an average grade of the particular ore body. So, this method is a method which we can think of first as a method which can be called which called as an included area method, where the drill holes are on the boundary of the area that chosen and there are 5 plus 5 10 plus 6, 16 locations of the boreholes which are on the boundary of the region and there are 9 boreholes which are in the centre.

If we presume that each representing about say 5 units in terms of 5 units of length then each will be represent, each will be an area of 25 since square meter or square whatever you for example, let us say there all space 5 meter intervals. So, these are representing about each will be 25 square meter and such 9 into their points will have an area of influence of 25 square meters each and the holes which will be on the boundary this 3 plus 3 plus 3 plus 3 this 12 boreholes on this will have exactly the half the area of influence compared to the interior points and the ones which are the fo4ur caller ones will have one fourth of the area of influence for them.

So, then if we if we want to calculate the say for example, the grade of this particular of the average, we want to represent in terms of average value for our global estimate. So, here the situation would be that for each offer, this each 9 boreholes it will be exactly the width that is coming out if we put in terms of W i. So, for the first if we consider then the width that is coming out to be W into the area square, whatever is coming as I will put as area square a square. So, there will be 9 such values 9 such points will be get where it will be W a square there will be 12 so; that means, I could say into 9, then here there will be 12 areas where the width will be multiplied by a square by 2 and there will be 9 there will be there will be 4 such areas where the width will be multiplied by area a square by 4.

And then if I sum, if I will sum them up together then I can always find out an average width, suppose I am assigned with calculation of the average width of the ore body then the average width of the ore body this summed up together divided by 25 will be the average width of this ore body.

And now if I am assigned with whatever parameter, if I if the if the assay value in terms of the grade which of let us say represents a g is known for each of the 25 points. So, then the average grade also could be exactly calculated in this formula by taking the area. So, suppose if the grade is calculated as the total width, say from the total width the volume could be calculated and the volume multiplied the specific gravity the mass could be calculated and by from the mass the value that is calculated in terms of the concentration of the metal this grade also could be calculated.

So, exactly the same applying the same method which we can demonstrate through workout exercise, the average width of the ore body the average grade of the ore body could be calculated and the average grade multiplied by the total volume that we can calculate for this ore body we can calculate what is the total amount of the metal could be present in terms of tonnes.

So, this is just a simple variation what of this method in which it is an excluded area method where all the boreholes are interior. So, the formula is very simple there will be 25 boreholes and for each borehole the width is measure. So, we will just calculate that for each borehole the area that is calculate and the width whatever would have got sum over them and divided by the total number of boreholes will get the average widths.

So, what we intended to get is the average width of the ore body and also similarly we want to calculate an average grade. So, this average grade is contributed by the grade that is a measured at every 25 points then divided by the total number of points that we have got its going to give us an average grade and that is the, that is the value which is which will be will report and then accordingly from calculation of the total mass of the ore body by multiplying the grade factor we know how much of metal could be present or this total ore that is calculated in terms of the in terms of times tonnes and million tonnes whatever will you need to a might reporting.

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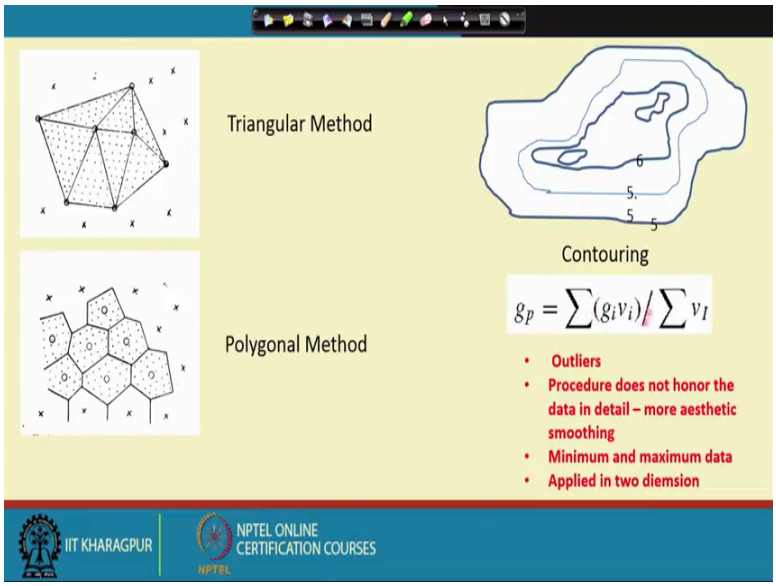

In some such situations this is the triangular method. So, there are many such points of drilling points where the ore body has been encountered and the width of the ore body is measured and also the grade is measured similarly, but they are not exactly in a regular grid pattern is shown before and they could be joined by into triangles and each triangle being represented by the average of the values that is determined 3 epical points and can similar where the total each volume can be calculated divided by the total number of points and the width and the total volume of the ore body and the grade can calculated.

Sometimes also if the drilling pattern has been such depending on the nature of the ore body that is there they could also be joined into, they could also be divided into such polygonal areas joining the points joining the points where the drill hole is drilled and then drawing perpendicular to that line. and several such series of such lines could be joined to divide the whole area into polygons and each point the width of the ore body and the grade of the ore body is known and the area of the polygons can be measured and also the volume and the mass of the ore body can be calculated exactly the same way by taking the weighted arithmetic average of that.

In some cases if the number of data points are more and the grid this spaces have been closely spaced it can also be some kind of contouring algorithm can be used where the different rates as for our, as per the choice of the grade interval which we can classify

into high grade, medium grade, low grade and then the cut off could be specified and contours can be can be reconstructed by using contouring standard contouring algorithms

And then the area each of the contour intervals area could is calculated and that the each segment is also is understood to have a single value of average width. Similarly for the different higher and higher grade areas which are contour this innermost part a represent with the highest value and also by the same way the volume of the ore body and the total mass by the simple formula, that the total grade the average grade is the grade of individual points where I is could be n these are n number of points where I varying from 1 to n. So, like g 1, v 1, g 2, v 2, g 3, v 3 divided by the total volume which will be measured total the grade into the individual volume into the grade divided by the total volume. So, that will give an average grade of this ore body. So, what exactly we intent to do is to calculate an average grade for reporting purpose.

Contouring algorithms will have their own problems because sometimes because of some analytical problems or even in reality somewhere occurrence of some very high grade material like it happens in case of the ore shoots the situation is that the contouring software's will generally be more for the aesthetic and the smooth joining of the points into the contours were such kind of out layer values also cannot be considered. And the minimum or the maximum data that would be required for such kind of contours also sometimes remember the subjective and its applied in 2 dimensions, but then these are also this also is one of the traditional method by which the average grade and the total quantity in terms of tonnage can be estimated for an ore body.

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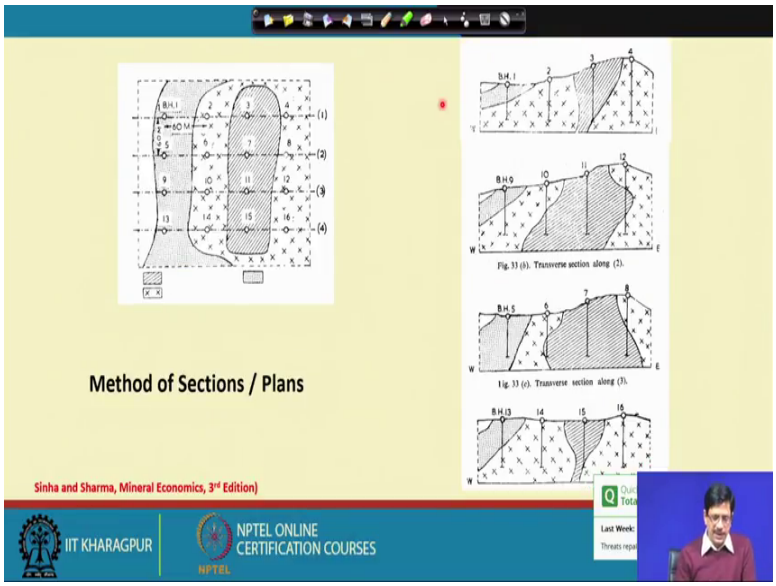

So, these are the example of the sections what I was just showing that if this is the plan view of the ore body that is exposed and then this kind of the drills ores are planned on a regular pattern, this 5 this 4 profiles are shown here in terms of the drill holes and from the reconstruction of the drill holes. So, each of the 16 drill holes are stacked or are studied together in considering the third dimension and the, this kind of sections. So, each represent a section depending on what is the depth to which the ore body has the drill hole has penetrated and such kind of sections can be prepared and from which we can also calculate the total volume and the of the ore body and the assay value the grade and the values can be calculated.

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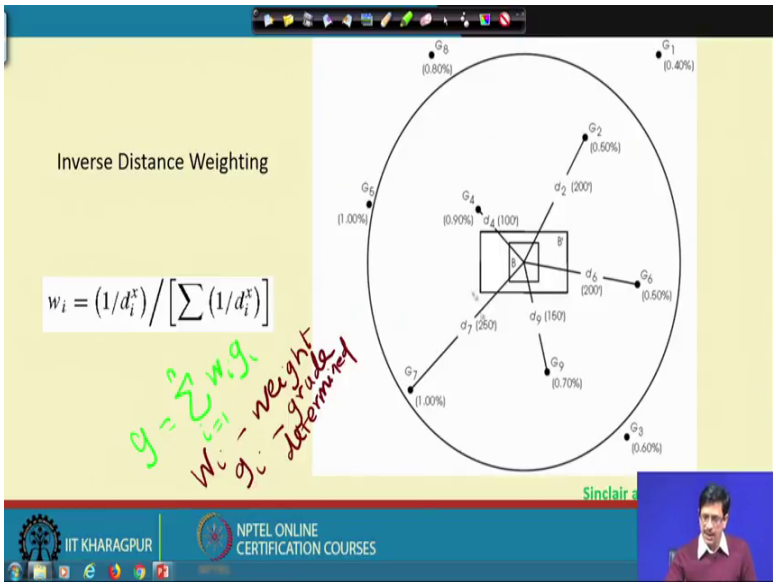

So, the this method is a the little more improved method which is taking into the spatial nature of the data this spatial variation and this is the inverse distance weighting method and it also you, it also is more is applicable when we are we have already, we already discussing about the ore body being discretized into a selective mining units of the blocks.

So, for example, depending on if we choose a block which is the one which is designated as B here this block or it could be a larger block that has been chosen here this represented as g prime, at this point represent the centre of the block and whatever grade is assigned to this centre of this block would apply for the centre block that is how is the practise in the mining.

And let us say for example, there are many points like from g 1 from g 1 to g 9 there is several such points where the drill hole data are available where the grade data are available. So, we want to compute what could be what grade should be assigned to the point centre point here irrespective of there is B or B prime.

So, these points are at unequal spatial space or unequal distance from the centre point which are united at g 1, g 2 could be represented as d 1, d 2, d 3, d 4, d 5 up to d 9 and we could see that the nearest point is possibly either d 4 g 4 where the d 4 is the nearest distance and the farthest could be g 7. So, d 7 could be the farthest distance and d 4 is the shortest distance.

So, the whole idea about this particular exercise is that the grade at this point of the centre, centre point of this block selective mining unit of the block is influenced by the values of the grade in the surrounding and the influence will be essentially be inverse to the distance. Means, the influence of point 4, g 4 will be the most and the influence of point 7 will be least and we could see here just for purpose of demonstration this g 1, g 8 g 5 and g 3 have not been taken into consideration. So, it is a matter of choice they could be taken into consideration or they may not be taken into consideration.

So, here this once it is realised that the value at the centre will be influenced by the value in their surrounding and the influence will be inversely proportional to the distance, means the shortest shorter is the distance greater is the influence. So, we will always represent that the grade if the spatial that the average grade g at the centre of the block would be equal to summation I equals to one to n w i, g i.

So, here W i is the weighting factor that w i is the weight and g i is the grade determined in all those locations I varying from 1 to n, 1 to for example, in this case there are we are taking 5 points g 2, g 6, g 9, g 7 and g 4 their distances are similarly d 9, d 6, d 2, d 4 and d 7.

And then this weight is actually estimated by a by a method which is very easy to understand the one by because we have said that this influence spatial influence is inversely proportional to distance. So, it will be 1 by d i rise to the power x.

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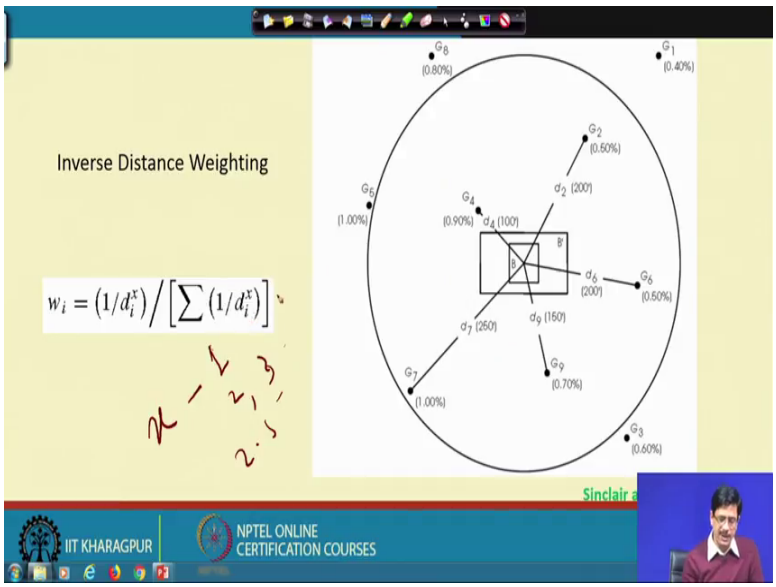

So, this rise to the power x could be could be our own choice it could be just one by d x could be one or x could be whole number going to 2 or 3 and or could be a part number even going to 2.5, this possibly could be determined by a different method. So, x represents the power. So, it is one by d i always has to be positive power not negative.

So, 1 by dix divided by the summation of all this terms of one by dix means it will go on like here it will be if there are 5 points. So, if I, if I talk of the point number so; that means, if I want to calculate what will be the weight for weight for point number 4, the weight would be 1 by d 4.

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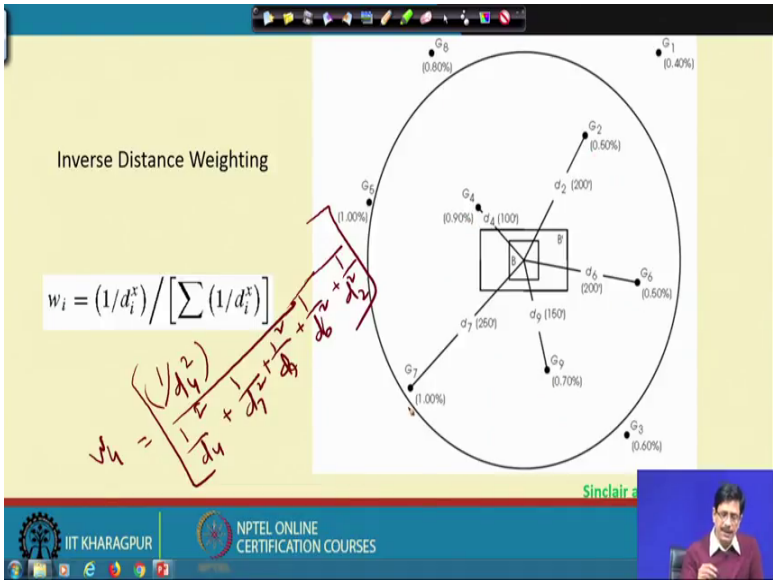

Suppose we say it is a squared. So, it could be d 4 square divided by 1 by d 4 square plus 1 by d 7 square plus 1 by d 9 square plus 1 by d 6 square plus 1 by d 2 square. So, this is what will be the value which will be coming out as for W 4 simple. So, each of the weight from W 4, W 2, W 6, W 9 and W 7 will be calculated.

And then the, what exactly is followed here is that the summation of all this ws wy should be equal to 1.

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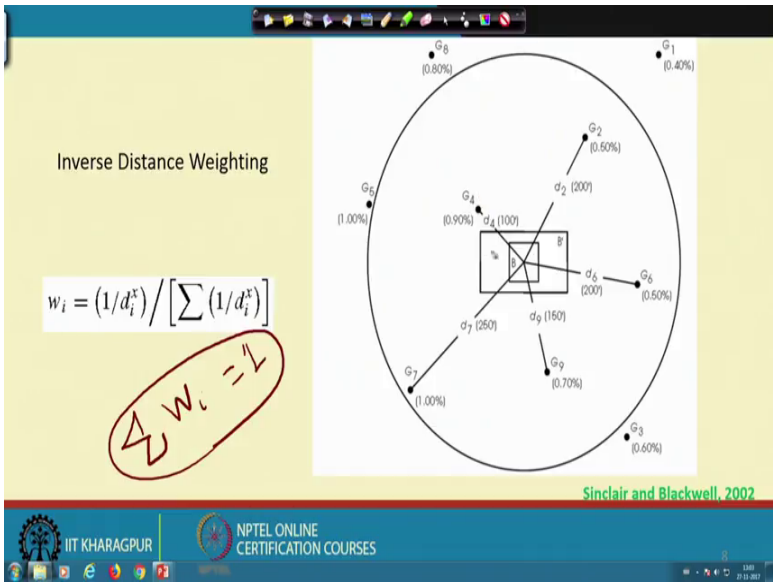

So, that so; that means, we can always supplement with a small exercise even the grades are also given here for example, in the g point number 4 it is point 9 and in the g 7 it is one and g 9 is 0.7. So, here each of the cases it will be 0.9 so; that means, for if we calculate the grade here then the grade at point b.

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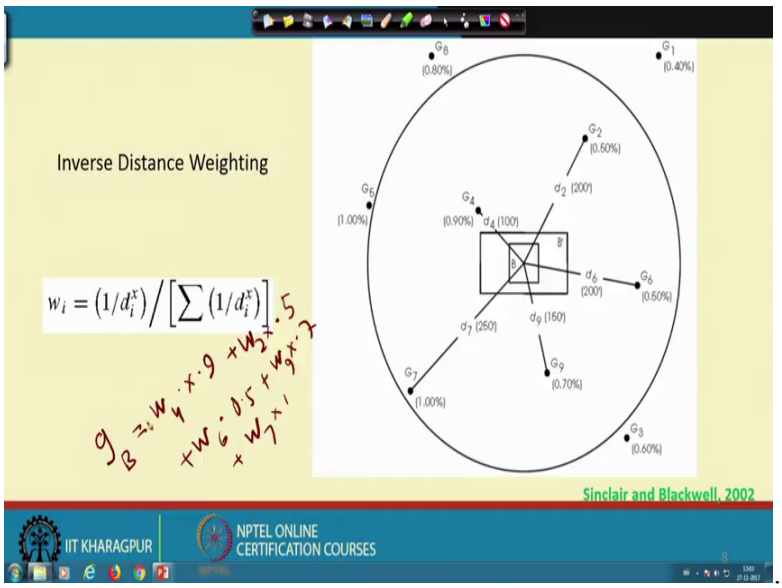

If we designate is grade at point b will be equal to W 4 into point 9 plus W 2 into 0.6 0.5 plus W 6 into 0.5 plus W 9 into 0.7 plus W 7 into 1.

So, this because we know that this W will be with the values of 0 to o1ne and all the summation of W 1, W ,4 plus W 2, plus W 6 plus W 9 plus W 7 will be equal to 1. So, we will get a value for this point the grade at point b which will be something intermediated between this the most and we can calculate. If we know the value if we work out the values of W by which will be which will do in a work out example, will see will we can always calculate the grade. So, that will be assigned that grade will be assigned to the point here.

So, depending on. So, if we choose a larger block size or you could choose a larger area. So, now, the question that would be that will come to our mind is that what is the confine or what is the limit of distance that we are going to choose. So, this. So, the choice of what is the spatial distance of the limit that will be choosing while calculating this weight is not a cannot be answered by very simple, with while discussing the simply calculation procedure.

Taken only be because in any case whatever grades were assigning here is definitely not the true grade it is the estimated grade and we have seen that how the situation works that most of the time we misclassify an ore to be waste or waste to be an ore keeping that aside we have to label a particular block as ore, as the ore or waste for our mining operations to be carried out and for the ore to be exploited.

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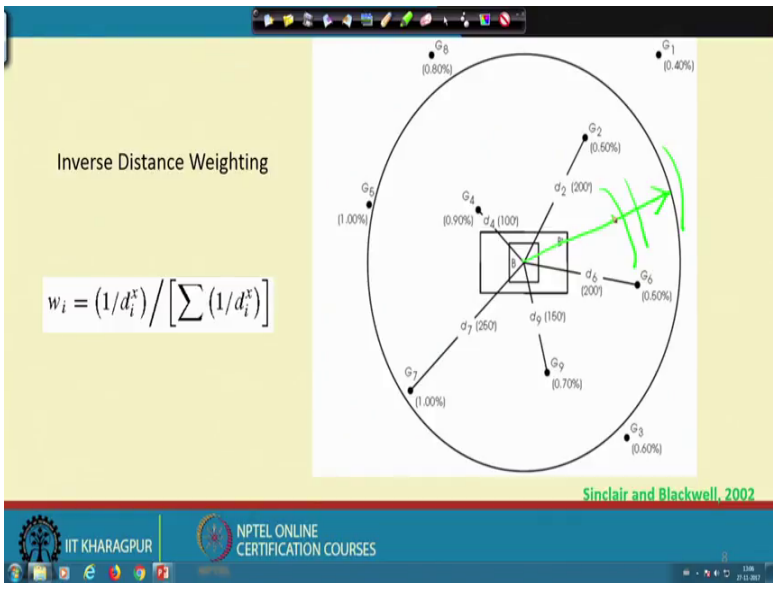

So, what exact spatial distance for example, if this is the if for example, if this is the centre then what should be the, what limit I should take. So, this becomes a this is the question that this limit where I should I should terminated here or here or here or go beyond this is a issue which will be sorted out when we look in to a little bit more details about the and using geo statistics; that means, the spatial the nature of the spatial data into account which will be explaining later.

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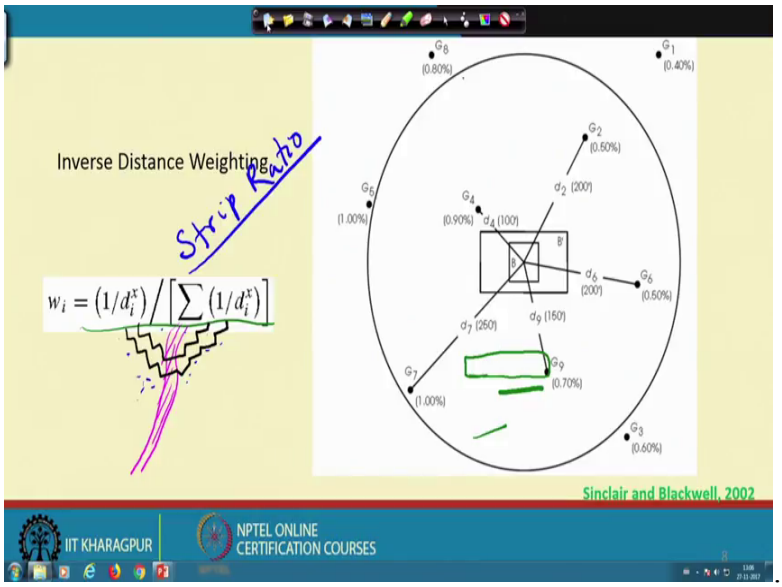

So, this is 1 example.

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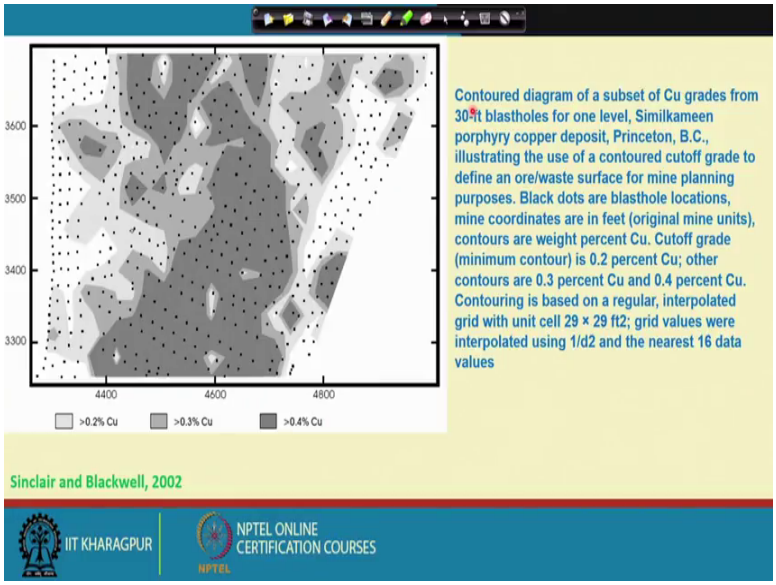

That if we have some such lots of such blast hole data. So, each black points are representing blast hole and the it is a the data has been taken from one copper in the porphyry copper deposit in British Columbia. So, here this values which are representing in the in the most front shape is greater than 0.2 percent 0.3 percent 0.4 percent and rest of is a will be cut off, cut off is 0.2, 0.2 percent and once we measure the values. So, we can contour them and this is one example of how it could be done and if the areas covered under this differently shredded part as belonging to high grade and intermediate grade and the grade exactly which is just above the cut off grade, can be area can be calculated the volume and the average grade and the total quantity is all can be calculated.

So, this go under the category of the traditional method of estimation of grade and the quality, quantity parameter for the ore body and we will continue discussing this go on to the discussion of the use of spatial geo-statistics in the coming classes.

Thank you.